4.4.7 Curing Temperature Results

The center line temperature of the triplex column was measured with thermocouples during curing to ensure that temperatures remained below 100°C. Above 100°C steam would be created and potentially entrain contaminants, which is undesirable. Figures 17, 18, and 19 show the curing temperature profile graphically for U.S. Grout, TECT HG, and GMENT-12, respectively. Tables in Appendix J summarize the time/temperature profile at mid-axial location for TECT HG, GMENT-12, and U.S. Grout. The thermocouples were inserted immediately following injection of each type of grout.

Examining the figures, the U.S. Grout reached a maximum centerline temperature of set of 48°C (118°F), 12 hours (720 min.) following insertion of the thermocouple and GMENT-12 reached a maximum temperature of set of 75.5°C (168°F), 14.3 hours (858 min) after insertion, and finally, TECT HG reached a maximum temperature of set of 74°C (165°F), 17.6 hours (1056 min) after insertion of the thermocouple. Therefore, all three grouts met the curing criteria in that the maximum temperature of set is below 212°F or 100°C.

4.4.8 Polyethylene Rod Removal Results

During the field test, a series of eight boreholes were required to perform hydraulic conductivity testing. To create these boreholes, a 7-cm (2.5-in.) polyethylene rod was inserted into a just-grouted hole. Following curing, the borehole was to be created by removing the polyethylene rod. A 7-cm (2.75-in.) polyethylene solid rod was inserted into one hole of the TECT HG triplex column. The polyethylene rod had a solid drive point attached to a metal rod that extended up through the center of the polyethylene rod. At the top of the metal rod was an "eye" lifting attachment.

The insertion was easily accomplished by manually pushing down the rod to full depth, which was 12 ft from the top of the thrust block (30 cm [1 ft] of thrust block, 0.9 m [3 ft] of overburden, and 2.4 m [8 ft] of grouted material). Allowing for 5 days of curing, the polyethylene rod was removed with some difficulty. The first attempt to remove the rod involved attaching the lifting ring located on the top of the polyethylene rod to a lifting strap attached to a backhoe bucket. The rod could not be removed with the standard backhoe in an extended position with the existing hydraulics. Next, the lifting strap was located in a chock-hold type arrangement using a pipe wrench for purchase on the smooth surface of the rod as shown in Figure 20.

This action allowed removal of the rod in about 60-cm (2-ft) lifts, with each lift demanding a change in position of the pipe wrench/strap combination. It is recommended that, during the field testing, a larger track-hoe be used to lift the polyethylene rod out using the designed lifting eye. If that fails, use the chocker method described above.

4.4.9 Destructive Examination of Resultant Columns

The destructive examination of the columns created under the thrust blocks first involved removing side burden material until the three monoliths were exposed as shown in Figure 21.

The thrust blocks were then toppled over into the created pit and the interior of the thrust block examined for sticking of the cured returned grout/soil on the interior surface of the thrust block (the interior surface of the thrust block was lined with closed cell foam liner). This was followed by complete excavation of the monoliths and removal in one piece for a photographic record.

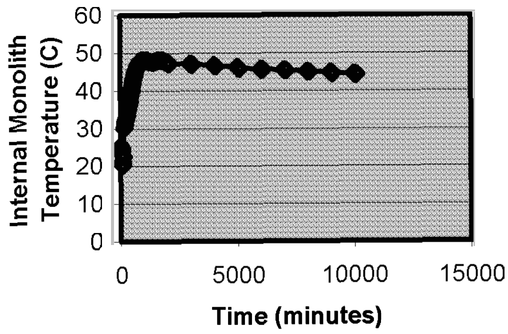

Figure 17. Curing temperature profile of U.S. Grout.

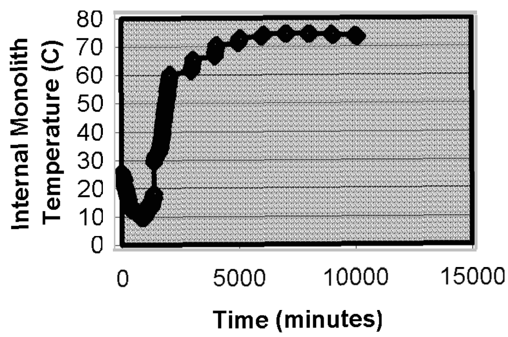

Figure 18. Curing temperature profile of TECT HG.

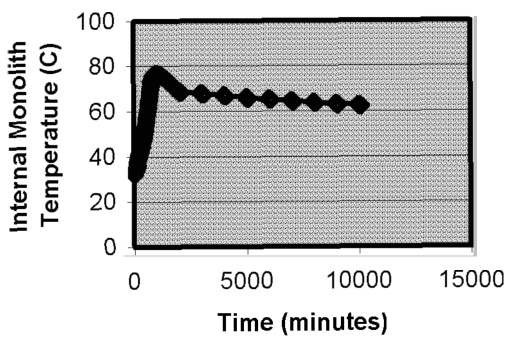

Figure 19. Curing temperature profile of GMENT-12.

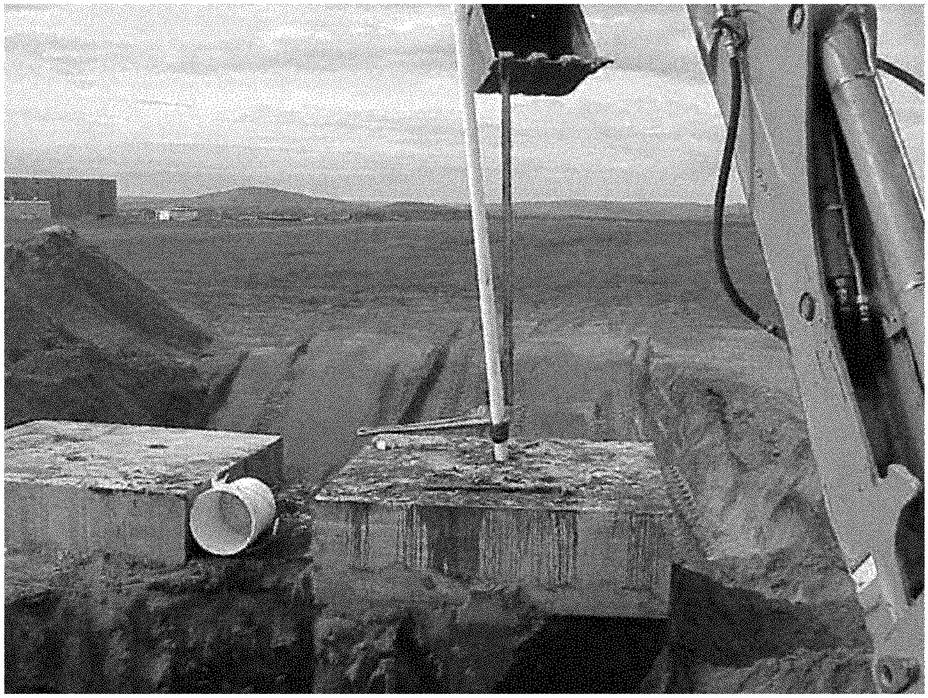

Figure 20. Lifting the polyethylene rod out of a grouted hole.

Figure 21. Excavation of the monoliths.

4.4.9.1 Removal of the Thrust Block

Thrust block undersurfaces had been coated with foam to eliminate sticking of grout return and to allow possible reuse of the thrust block. Following grouting, the thrust blocks were examined for sticking of the grout. All thrust blocks were removed, and, as expected, the U.S. Grout thrust block was completely full of cured grout. The grout stuck to the surface of the foam and could not be removed, even after lifting and dropping the thrust block with a front-end loader. The TECT HG grout exhibited a similar effect in that it also showed the entire grout return stuck to the foam liner.

For the GMENT-12 grout, however, the entire return came out in one piece, leaving the thrust block empty during the process of rolling the thrust block off the top of the monolith. Figure 22 shows the underside of the GMENT-12 thrust block, with the solid block of cured grout returns basically fallen out of the block during excavation.

This compares to the U.S. Grout thrust block in which the entire grout return not only is stuck to the Styrofoam but the block is confirmed full of cured grout (Figure 23).

It is concluded that generally the blocks are not reusable and that the GMENT-12 grout exhibited the best tendency for not sticking to the Styrofoam. Reuse of the blocks would be a potential for the GMENT-12 grout only.

4.4.9.2 Examination of the GMENT-12 Monolith

The GMENT-12 monolith was isolated on three sides, photographed and measured. The GMENT-12 monolith is on the left side of the photograph shown in Figure 21.

Using the front-end loader, the monolith was completely removed in one stand-alone piece of the mixtures of soil and grout. The monolith was measured at 2.4 m (8 ft) high by roughly 1.2 m (48 in.) in diameter. This represents a volume of 2,838 L (751 gal), and 1,360 L (360 gal) of grout was injected with 181 L (48 gal) of returns, or a net 1,179 L (312 gal) into the monolith. This equates to a void filling of 41%.

An attempt was made to break up the monolith using a standard backhoe bucket by raising the bucket above the monolith about 60 cm (2 ft) and striking the monolith. Only small fragments could be obtained after repeated blows, suggesting a strong cohesive monolith (Figure 24).

4.4.9.3 Examination of the TECT HG Monolith

The monolith created by the injection of TECT HG grout in a triplex column was a solid cohesive stand-alone monolith as shown being moved out of the pit in Figure 25.

The dimensions of the monolith averaged about 109 cm (43 in.) throughout the length of 2.38 m (7 ft 10 in.) with a reduced section or ledge in the top portion caused by running out of TECT HG grout during the grouting of the last hole. A total of 1251 L (331 gal) of grout were injected with 355 L (94 gal) of returns giving a net volume injected into the monolith of 895 L (237 gal). The size of this monolith equates to an approximate volume of 1950 L (516 gal) of column. Accounting for an approximately 0.6 m (2 ft) diameter by 0.6 m (2 ft) high reduction in the region not grouted due to running out of grout equates to a void filling of 45% which is in good agreement with the GMENT-12 created monolith. An attempt was also made to break up the stand-alone monolith with the backhoe and after repeated attack, only small chunks could be broken off again suggesting a solid cohesive monolith. The hole created by the polyethylene rod inserted into the TECT HG monolith produced a smooth hole for performing U.S. Bureau of Reclamation packer testing as shown in Figure 26.

Figure 22. GMENT-12 thrust block (underside showing Styrofoam liner).

Figure 23. Underside of U.S. Grout thrust block.

Figure 24. GMENT-12 monolith removed as one piece from the pit.

Figure 25. TECT HG monolith being moved as one piece.

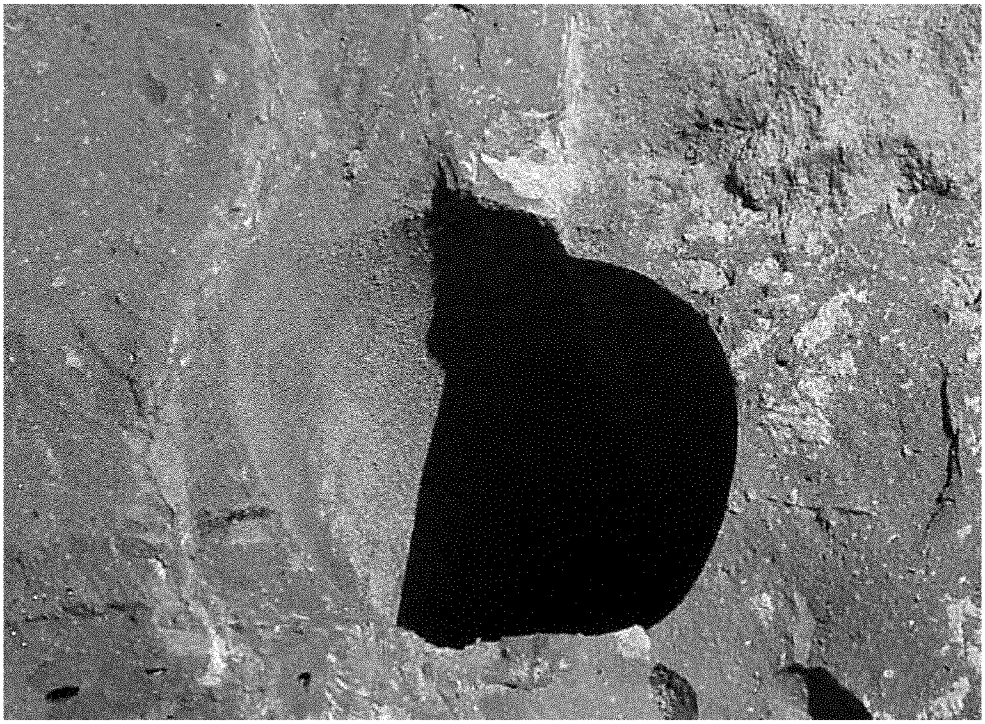

Figure 26. Hole created by insertion of the polyethylene rod.

4.4.9.4 Examination of the U.S. Grout Monolith

The U.S. Grout monolith also was a cohesive stand-alone piece of the mixtures of soil and grout as shown in Figure 21 on the right. The monolith was irregular shaped in that only 1 full column and 1 half column was grouted prior to filling the block with grout returns. The approximate volume of the column was that 1.2 m (4 ft) of the column had a mean diameter of 109 cm (43 in.) and the other half had a mean diameter of 84 cm (33 in.) which equates to an approximate volume of column of 1806 L (478 gal) of the mixtures of soil and grout. This compares to the amount of grout injected into the column of 532 L (141 gal) which means that the injection process filled 29% of the voids considerably lower than the void filling for the GMENT-12 and TECT HG grouts. It is possible that the relatively low specific gravity (U.S. Grout-1.6, TECT HG-2.16, GMENT-12-1.84) did not impart the same energy to the soil and therefore, the penetration of grout was lower.

4.4.10 Down-Selection of Grouts for Field Testing

Based on implementability testing of the three grouts, GMENT-12 was chosen as the single grout to carry forward for field testing. GMENT-12:

- Displayed the lowest grout returns/grout delivered ratio.
- Displayed the best ease of operation using simple dry ingredients and displayed a fairly straightforward cleanup.
- Was cost competitive with the other grouts.
- Produced a good monolith soil.
- Laboratory results for hydraulic conductivity, leach, physical strength, set conditions, where competitive.

5. FIELD TESTING

Field Testing was performed at the INEEL Cold Test Pit South which is located immediately south of the INEEL RWMC SDA. The testing was to involve a field preparation phase, a grouting phase, a hydraulic conductivity measurement phase and finally, a destructive examination of the resulting monolith. Due to a catastrophic failure of a fitting on the high-pressure pump and a resultant injury to a member of the subcontractor's team, only part of the grouting phase was performed. The project was not truncated due to safety issues, rather, there was a simultaneous compelling need for the remaining budget to cover the costs of other higher priority Environmental Restoration Projects. In addition, the cost of restart may have been prohibitive. Restart would have required new pressure relief systems and verification of operability, new procedures, and a rigorous operational readiness process. However, during this limited grouting operation, full contamination control data was obtained in enough detail to evaluate the contamination control features of the thrust block concept for jet grouting transuranic pits and trenches. What follows is a description of rest site construction, the testing hardware, mobilization processes, evaluation of the limited grouting operation, and finally, an evaluation of the contamination control system involving the thrust block and shroud systems.

5.1 Preparing for Grouting

5.1.1 Site Preparation

To perform the grouting demonstration, a pit simulating statistically average conditions in the INEEL SDA transuranic pits and trenches was constructed. The pit dimensions were 4.57 m (15 ft) by 4.57 m (15 ft) by 2.4 m (8 ft) deep. Waste in the pit was typical of that buried in the SDA including containerized cloth, paper, wood, asphalt, sludges, and metals. The backfill soil used in the demonstration represent exactly soil types, mineralogy, permeability, as seen in the SDA. Details of the pit construction and design rationale are documented in Shaw (2000).

5.1.2 Simulated Waste Preparation

A combination of SDA-wide waste volumes and specific details of Pit 6 at the SDA were used as a model for defining the simulated waste container volumes and waste material. Pit 6 was chosen as a model primarily because the average depth of buried waste is approximately 8 ft (2.4 m), simplifying the retrieval process for the treatability study. Table 28 shows the SDA-wide volume fraction of buried waste broken down into seven major categories. These include combustibles, organic sludge, inorganic sludge, nitrate sludge, metal, concrete, and asphalt. For example, on a volume basis, approximately 53% of the waste volume in the SDA comprises combustibles such as cloth, paper, plastic, and wood. Table 29 shows that the waste volume in Pit 6 approximately equals 50% of the excavated volume, of which 46% is drummed waste (55-gal [208-L] drums), 33% is boxed waste (wooden 4 × 4 × 8-ft [1.2 × 1.2 × 2.4-m] boxes), and 21% is cartoned waste (cardboard boxes of combustible material).

Applying the SDA waste loading rationale presented in Tables 28 and 29 to a 15 × 15 × 8-ft (4.5 × 4.5 × 2.4-m) deep test pit area, two 4 × 4 × 8-ft (1.2 × 1.2 × 2.4-m) boxes, 49 55-gal (208-L) drums, and 14 nominally 2 × 2 × 3-ft (0.6 × 0.6 × 0.9-m) polyethylene sacks were randomly configured in the test pit. Table 30 summarizes information relative to the type and contents of the simulated waste packages for the disposal pit. Metal debris including plate steel, tubing, and scrap metal was hand placed in two of the boxes along with concrete, asphalt, and wood. Boxes contain approximately 38% metal, 37% concrete and asphalt, and 25% wood as shown in Figure 27. Of the 49 drums, 25 contained combustibles that included cloth, paper, wood, and plastic, 13 contained inorganic sludge, six contained organic sludge, and five contained nitrate salts (shown in Figure 28). Three of the organic drums were metal sided drums, and

Table 28. Volume fractions of buried transuranic waste in SDA.

Waste Type	Volume (m^3)	Fraction of Total
Organic	3,696	0.059
Nitrate	2,480	0.043
Inorganic	7,361	0.124
Brick and concrete	7,570	0.117
Metal	7,445	0.121
Combustible	33,480	0.536
Total	62,032	1.000

Table 29. Pit 6 waste and soil volumes.

Total Excavated Volume	Soil Volume	Waste Volume
447,515 ft^3 (12,672 m^3)	223,617 ft^3 (6,332 m^3)	223,898 ft^3 (6,340 m^3)

Waste Type by Volume		
Waste Type	Volume	Fraction of Total
Drums	102,272 ft^3 (2,896 m^3)	46%
Boxes	73,918 ft^3 (2,093 m^3)	33%
Cardboard	47,708 ft^3 (1,351 m^3)	21%

Table 30. Simulated waste packages for the disposal pit.

Waste Container Type	Number	Composition
Cardboard boxes (4 × 4 × 8 ft)	2	Metal debris (1/8-in. plate steel, tubing, piping, scrap metal), concrete/asphalt chunks (6-in. size), pulverized wood. Metal 38%, concrete/asphalt 37%, pulverized wood 25%.
Cardboard	25	Combustibles (cloth, paper, wood)
Cardboard	13	Inorganic (enough water to create a paste like consistency; 390 lb_m soil; 40 lb_m dry Portland cement; 36 lb_m $NaNO_3$)
Cardboard	3	Organic (38 gal of Texaco Regal Oil; 65 lb_m Micro Cell-E; 35 lb_m kitty liter)
Metal	3	
Cardboard	3	Nitrates (granular: 60 wt% $NaNo_3$; 30 wt% KNO_3; 5 wt% Na_2SO_4; 5 wt% NaCl
Metal	2	
Sacks (2 × 2 × 3 ft) (polyethylene)	14	Cloth, paper.

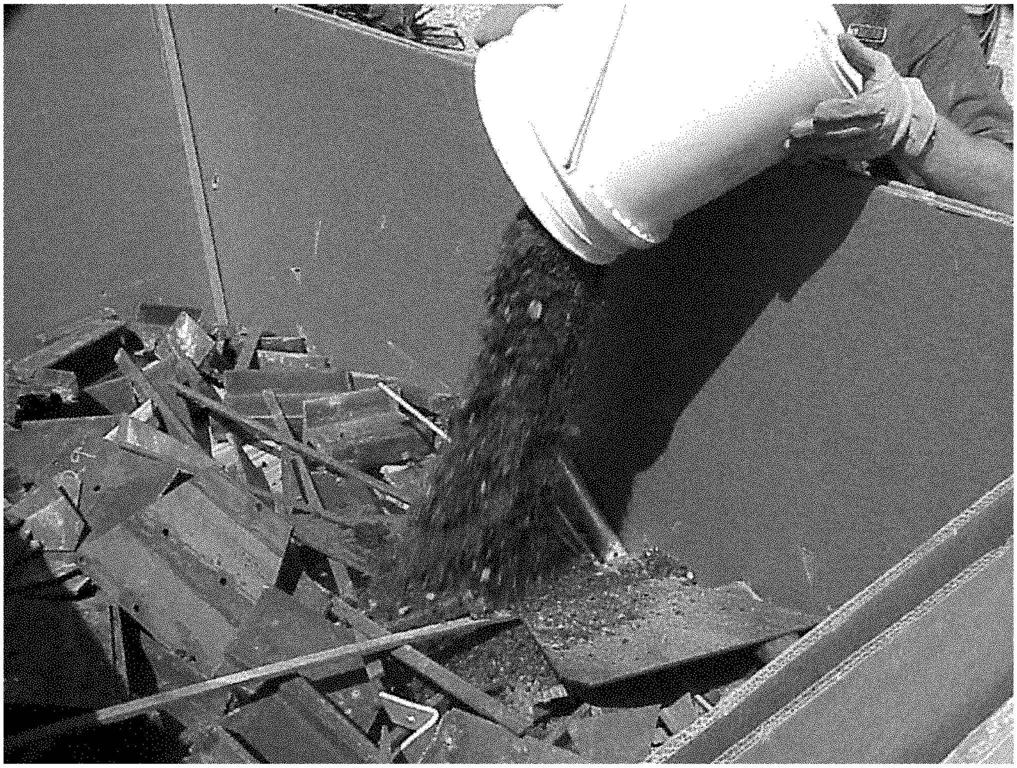

Figure 27. Box being filled with metal, wood, asphalt, and concrete.

Figure 28. Drum filled with nitrate salts.

two of the nitrate drums were metal sided drums. All other drums were cardboard drums to simulate the aging process that is expected to have occurred in the SDA transuranic sites and trenches. Fourteen sacks were filled with cloth and paper. A terbium oxide tracer was placed in each container (except nitrate drums) to simulate the mechanical movement of plutonium during operations. The combustible drums contained 3.5 oz (100 g) of tracer, the boxes 14 oz (400 g), the inorganic drums 7 oz (200 g), the organic drums 1.75 oz (50 g), and the sacks 3.5 oz (100 g). On a one-for-one basis it is estimated that this tracer loading represents maximum plutonium loading in the actual transuranic waste.

5.1.3 Waste Pit Construction

Except for the two boxes, the drums and sacks were placed in the test pit in a random orientation simulating the random dumping that occurred within the INEEL SDA. Figure 29 shows the general design features of the disposal pit including a 2-ft (0.6-m) compacted soil underburden, a 3-ft (0.9-m) overburden, a seam of simulated waste and soil 8 ft (2.4 m) thick, and standard thrust block approximately 17 in. (43 cm) thick with space for grout returns. Pit dimensions are 15 × 15 ft × 8 ft (4.5 × 4.5 × 2.4 m). The layout of the simulated waste in the Cold Test Pit South was designed generally to represent a random dump zone in the SDA pits and trenches. However, many of the drums were strategically located relative to drill hole locations (defined by the hole orientation on the top of the thrust block) to maximize the amount of information collected from the emplaced monolith. Because the hydraulic conductivity measurements (local packer tests) were to be made within the same holes used for grouting, positioning certain waste containers directly under these holes allows examination of the maximum effect that material in the waste container has on local hydraulic conductivity.

There are two general waste composition types: (1) material that will not generally affect grout curing such as combustibles and debris (cloth, metal, soil, asphalt, concrete, and wood), and (2) material that could interfere with grout cure (nitrates and organics). Because of the proportionally small volume of organics and nitrate sources in the SDA, the most representative monolith hydraulic conductivity conditions are near these interference materials but not within an actual penetration of the interference drum. Based on historical data, the volume of the nitrate and organic interference is approximately 10% of the volume of the pit while 90% of the volume is void or containerized soil or cloth, paper, wood, asphalt, metal, glass, and other debris (Vigil 1990).

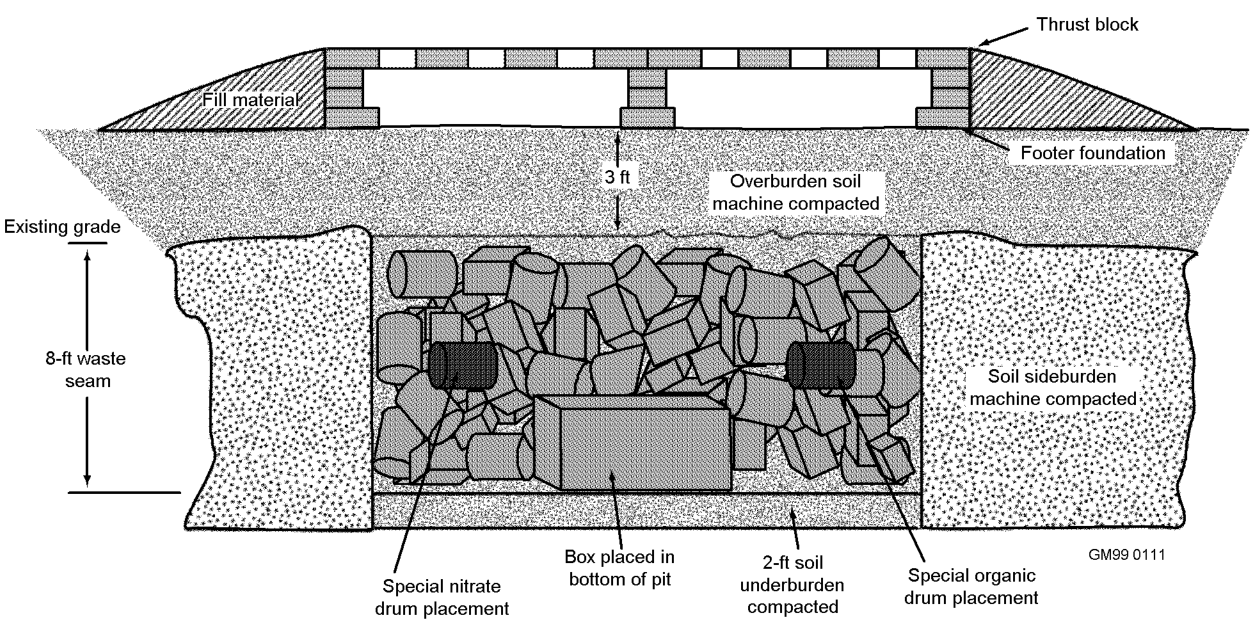

Figure 29. Design features of the long-term disposal pit.